RESULTS

Both polygon and point-based analysis techniques revealed high rates of channel margin erosion in the study area. Channel margins classified as intertidal bars, marsh, dredge spoil, and uplands all experienced net erosion. Channel margins classified as water were excluded from analyses due to the ambiguities involved in the interpretation of accretion and erosion of these areas. Exposure to wakes generated by vessels in the AICW was the causal factor most strongly correlated with higher rates of erosion. Detailed results of the polygon and point-based analyses further illustrate the extent of erosion and the relationship of erosion rates with causal factors.

Polygon-based analysis

The area of channel margin lost to erosion in the study area from 1970/1971 to 2002 was found to far exceed the area replaced through accretion. Instead of an accretion/erosion ratio of approximately 1 that would be expected in light of previous work (Letzsch and Frey, 1980), from 1970/1971 to 2002 the ratio of accretion to erosion in the study area was 0.13. The total tidal channel area, as defined by the digitized channel margins, expanded 11.4% from 656.0 hectares (1621.0 acres) in 1970/1971 to 730.7 hectares (1805.7 acres) in 2002. Excluding channel margins attributed as water, 68.2 hectares (168.6 acres) of marsh, intertidal bars, marsh, spoil areas, and uplands were lost to erosion and not replaced through accretion. These findings are summarized in Table 3 below.

Table 3: Summary of area eroded 1970/1971 to 2002

Margin classification	Proportion of margin length	Area in hectares [acres]					
		Erosion		Accretion		Net change	
intertidal bars	15%	21.0	[51.8]	0.1	[0.1]	-20.9	[-51.7]
marsh	42%	26.4	[65.2]	10.2	[25.2]	-16.2	[-40.1]
dredge spoil	33%	28.7	[71.0]	0.1	[0.2]	-28.7	[-70.8]
upland	10%	2.7	[6.7]	0.3	[0.8]	-2.4	[-6.0]
Total	100%	78.8	[219.1]	10.6	[26.2]	-68.2	[-168.6]

Point-based analysis

While information concerning the area of channel margin habitat eroded is useful in the evaluation of the ecological impacts of erosion, the approach used in this analysis obscures the impacts of specific causal factors. In order to discern the relative impact of individual potential causes, it is necessary to eliminate the spatial variability in exposure which occurs within individual polygons. Comparison of points along the channel margin in 1970/1971 and 2002 allows association of rates of change with discrete sets of causal factors. Table 4 summarizes the lateral erosion data obtained from point comparisons along all non-water margin types.

Table 4: Summary of lateral movement from 1970/1971 to 2002

Margin classification	Proportion of margin length	Count of measurement points	Mean linear movement (m)
intertidal bars	15%	870	-23.2
marsh	42%	2477	-9.3
dredge spoil	33%	1930	-16.7
upland	10%	613	-4.6
Total	100%	5890	-13.4

Comparison of Tables 3 and 4 reveals that although the largest loss to erosion in terms of area was from dredge spoil margins, intertidal bars were subject to a higher rate of lateral erosion. Upland areas experienced both the lowest level of loss of area and the lowest rate of lateral erosion. Marsh margins ranked third in both in terms of area eroded and lateral rate of movement. In Figure 12, rates of lateral erosion are depicted graphically according to margin classification.

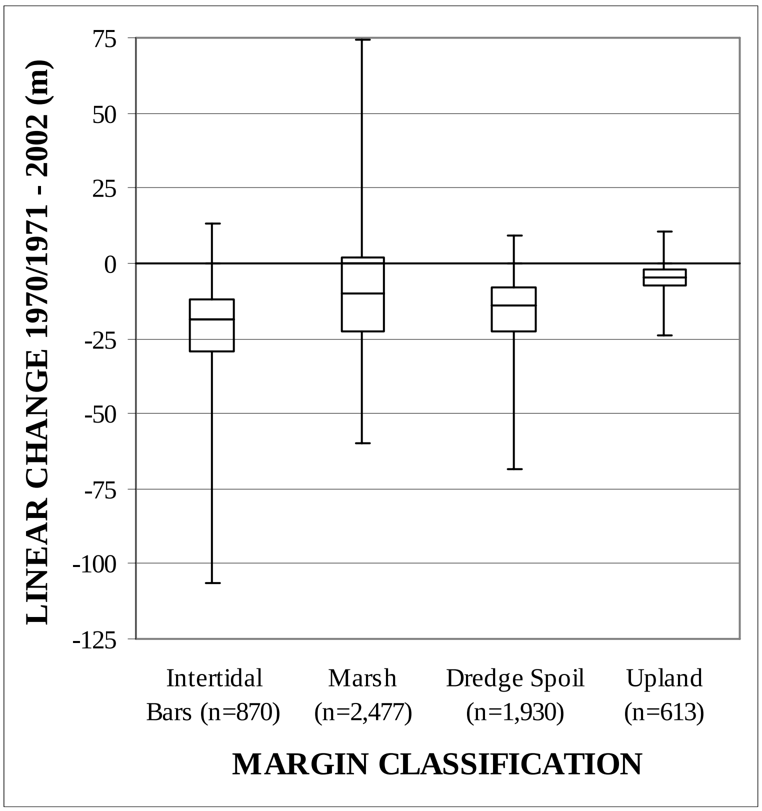

Fig. 12: Minimum, maximum and quartile rates of lateral movement from 1970/1971 to 2002 classified by margin type (n = number of points classified as each margin type)

A Kruskal-Wallis test showed that the rate of channel margin movement of at least one of the margin classifications was significantly different ($p < 0.0001$) than the others. A subsequent

Tukey's studentized range test was used to conduct pair-wise comparisons among all of the mean ranks of all of the margin classes. All comparisons showed significant differences ($p<0.05$).

Wilcoxon rank sum tests revealed significant differences ($p < 0.0001$) in the amount of lateral movement at points exposed and not exposed to both the AICW channel and waves generated by predominant winds. To discern the relative impact of these two factors, lateral rates of movement for points exposed to no significant causal factors, to only wind waves generated by predominant winds, to only boat wakes generated in the AICW channel and to both boat wakes and wind waves were compared. A Kruskal-Wallis test showed that the rate of movement for at least one of the causal factor combinations was significantly different ($p < 0.0001$) than the others. A Tukey's studentized range test revealed significant differences ($p<0.05$) in channel margin movement in all possible causal factor, pair-wise comparisons except the "exposed to no apparent causal factors" and the "exposed to wind waves only" categories (see dashed box in Fig. 13). The fact that this comparison was not statistically significant may be associated with the relatively small sample size and limited fetch available at points exposed only to wind waves. These points were located along secondary channels and were protected from boat wakes and the longer fetch found in the AICW.

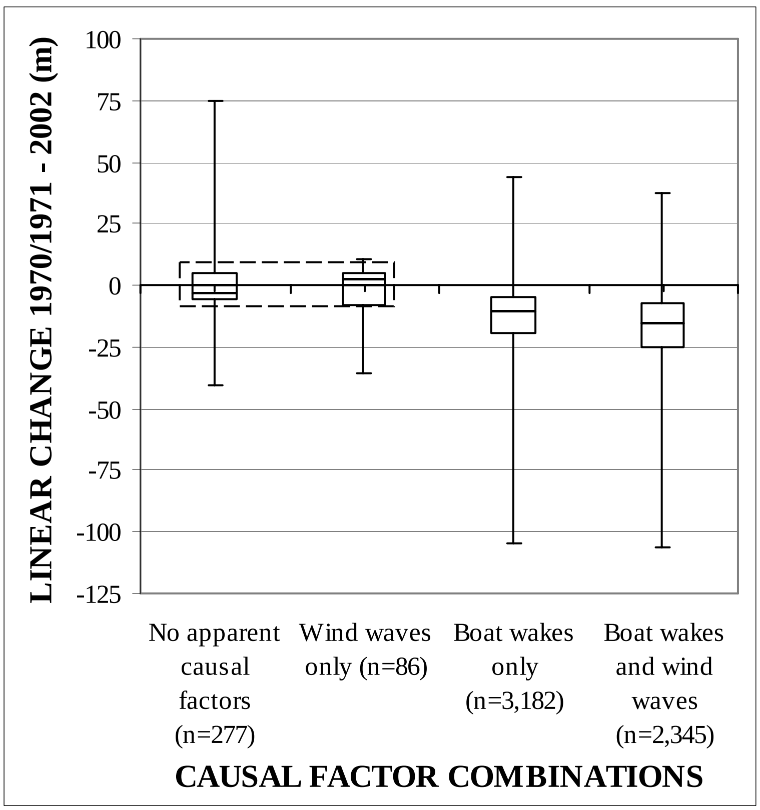

Fig. 13: Minimum, maximum and quartile rates of lateral movement from 1970/1971 to 2002 classified by exposure to causal factors, dashed box surrounds factors for which median values were not significantly different ($p>0.05$)
(n = number of points classified as exposed to each causal factor combination)

In order to develop estimates of 1970/1971 to 2002 lateral movement, given variations in and interactions between margin type and exposure to causal factors, dichotomous variables for each margin type, for exposure to boat wakes generated in the AICW channel, and for exposure to wind waves generated by the predominant wind were entered into a least squares linear regression model (see Table 5).

Table 5: Regression of lateral movement on significant causal factors and margin type

Source	DF	F value	Pr > F
model	5	255.69	<0.0001
total	5889		
R-Square	0.18		

Variable	Coefficient	t value	Pr > |t|
intercept	8.30	8.57	<0.0001
intertidal bars	-17.56	-23.11	<0.0001
marsh	-5.65	-8.60	<0.0001
spoil	-10.88	-15.91	<0.0001
exposure to wind waves	-1.98	-5.04	<0.0001
exposure to boat wakes	-13.03	-16.29	<0.0001

All coefficients in this model are significant and the very large overall F-value reveals that the variance explained by the model is significantly greater than the variance due to model error. However, the R^2 value of 0.18 reveals that much of the variation in the rate of channel margin movement remains unexplained by the model. This unexplained variation may be due to the fact that the regression attempts to explain all of the variation in a continuous dependent variable with binary independent variables. It also could be a reflection of the use of blunt measures which do not capture small scale variation in bathymetry and sediment type, and thus do not precisely reflect the level of erosive energy at the channel margin.

Due to this unexplained variation, the model may not be suitable for predicting movement at individual points; however, it can be used to estimate mean rates of lateral movement based on exposure to causal factors and margin type. The data in Figure 14 were calculated using the regression coefficients. Mean rates of lateral movement for each exposure and margin combination, as estimated by the regression model, were multiplied by the total margin length. These products were then multiplied by the proportion of the entire margin classified as each margin type and as exposed to each combination of causal factors. The result is an estimate of the change in area of each margin type associated with each causal factor. This figure indicates that due to the number of points susceptible to boat wake erosion, the total loss in area associated with boat wake exposure is much greater than that associated with exposure to other factors.

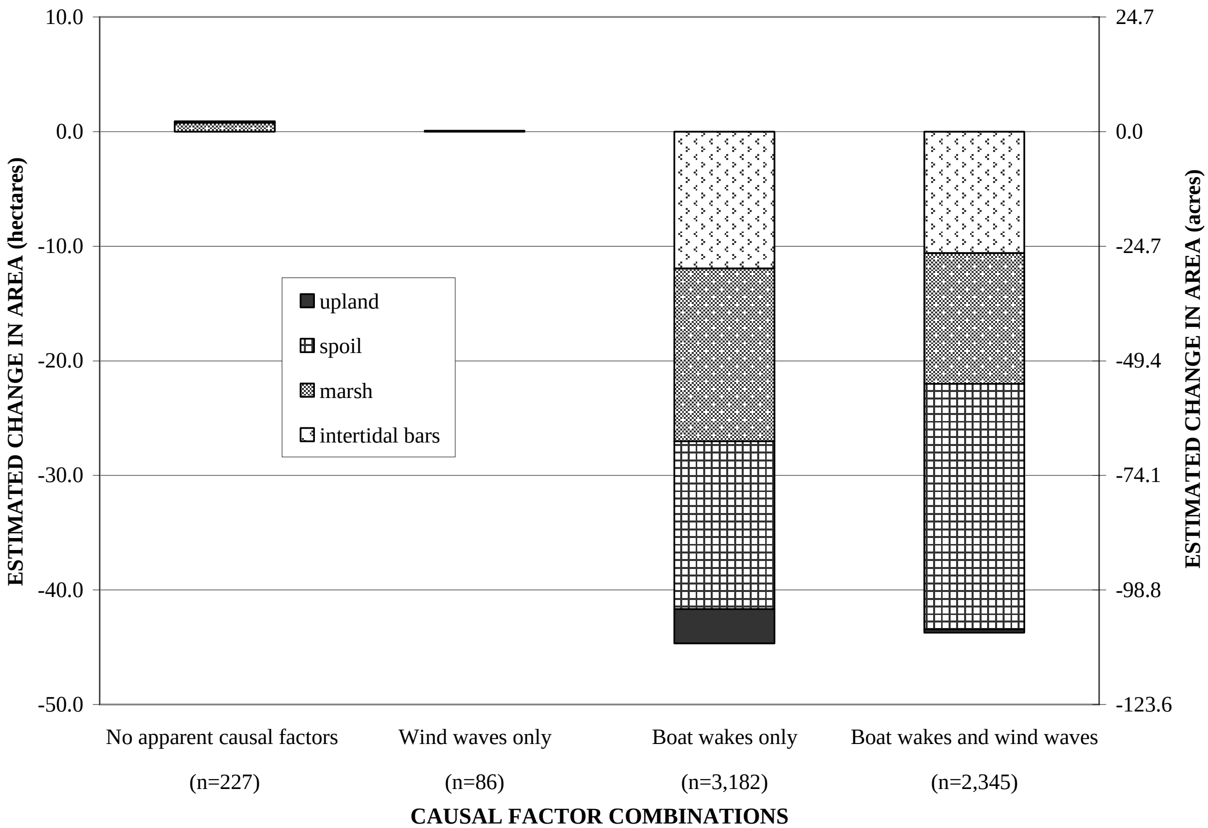

Fig.14: 1970/1971 to 2002 change in area estimated from rates of lateral movement (n = number of points exposed to each causal factor combination)

In order to address the problem of the low explanatory power of the regression model resulting from the use of binary independent variables to explain a continuous dependent variable, the Kendall's Tau-b correlation coefficients were calculated for channel margin movement rate and <u>all</u> points exposed to each of the causal factor combinations (Table 6).

Table 6: Correlations of causal factors and channel margin movement

Variable	Kendall's Tau b coefficient	p value
exposure to wind waves	-0.14	<0.0001
exposure to boat wakes	-0.20	<0.0001

Kendall's Tau-b can be interpreted as a measure of the percentage of variation in the dependent variable explained by the independent variable. While this non-parametric statistic is a more effective measure of correlation with binary independent variables than ordinary least-squares regression, it is limited in that it fails to account for interaction among the causal factors and the margin classification. It also does not help to overcome the coarseness in the measurement of the binary independent variables. These data constitute further evidence that simple exposure to boat wakes explains approximately 20% of the variation in channel margin movement.

Insignificant and marginally significant variables

Simple linear regression analysis revealed no significant correlations between channel margin movement and any of the three continuous causal variables, radius of curvature, distance from the 1999 AICW channel, and 1970/1971 channel width. A Wilcoxon rank sum test revealed no significant difference in the rates of movement for points coded as exposed or unexposed to significant tidal currents. Examination of bathymetric cross sections of the nine identifiable bends in the study area also provided no strong evidence of tidal current caused erosion.

The binary variable involving location relative to the State Road 206 Bridge, intended as an indicator of the impact of dredging, was found to be related to a small (2m over study period), but significant difference in margin movement. However, instead of erosion being more severe in dredged areas, it was actually less severe. There is no obvious explanation for this finding, but it could be related to the difference in the sediment type and level of shoreline stabilization in areas north and south of the bridge. The variable was not included in the final regression model because, although the coefficient was significant ($p<0.05$) its inclusion resulted in only a 0.0025 increase in the R^2 value.